

GROUND WATER IN IGNEOUS AND METAMORPHIC ROCKS; LOW-ANGLE LITHOLOGIC CONTACTS RELATED TO SITE-SPECIFIC CONTROL OF GROUND WATER OCCURRENCE

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Abstract. Because of well-established empirical relationships, it is common practice to site water wells in igneous and metamorphic rocks near lithologic contacts. In highly eroded fold mountain ranges such as the southeastern U.S. Piedmont/Blue Ridge, major lithologic contacts generally have a structural orientation similar to that of internal compositional layering and/or foliation. There are, however, areas where the lithologic contact relationships are quite different from the structural attitude of compositional layering, foliation, schistosity, or gneissosity. Recognizing, and being able to determine, the contact relationship can be a major factor in obtaining positive results in ground water exploration.

INTRODUCTION

Ground water movement in igneous and metamorphic rocks is controlled largely by: rock type (lithology); discontinuities due to compositional differences and fractures (joints and/or faults); topography; depth of weathering; nature and size of the recharge area and discharge area; and the spatial relationships of these factors.

Pronounced differences in lithologies cause rocks to react quite differently to deformational stress and to weathering. Along and near such lithologic contacts, differential weathering may create zones of enhanced permeability. Also, such primary differences may cause significant differences in secondary characteristics of the rocks, produced by deformation and weathering. These include presence or absence, and spacing, of joints and other fractures; and the nature and extent of weathering. Such features provide the secondary permeability which allows infiltration of precipitation and movement of ground water. Because the relationships outlined above have been well established, it is common practice to investigate lithologic contacts and contact zones as potential sites for drilling water wells; and as a guide to the subsurface distribution

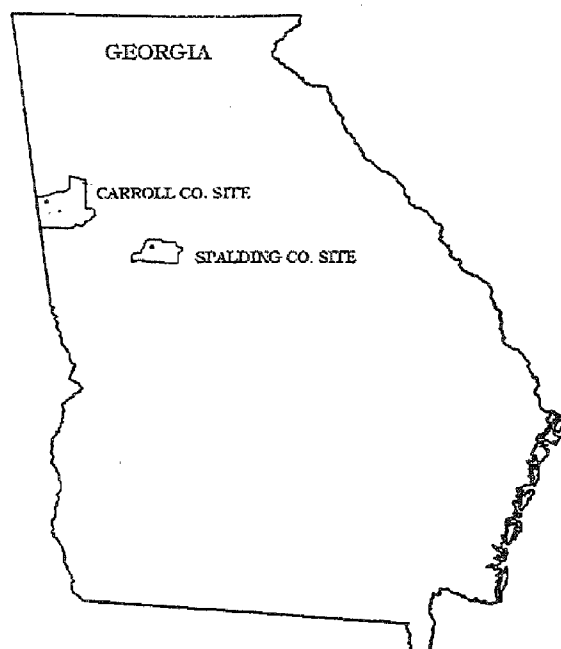


Figure 1. Study Area Locations

of the target lithology, which will offer the best potential for yield.

In a highly eroded fold mountain range such as the southeastern Piedmont/Blue Ridge, major lithologic contacts generally have a structural orientation similar to internal compositional layering and/or foliation. In much of the Piedmont/Blue Ridge, the inclination (dip) of such contacts is moderately steep to very steep. Because of this, in the siting of water wells based on this (contact) criterion it is generally sufficient to site the well a few tens of feet from the contact, the exact position depending on the dip magnitude and the depth at which you intend to intersect the contact zone.

There are areas, however, where the lithologic contact relationships are quite different from that described above; where the structural attitudes of lithologic contacts are not coincident with the structural attitudes of compositional layering, foliation, schistosity, or gneissosity. Failure to recognize this can lead to significant financial waste and negative results in ground water exploration. Recognizing, and being able to determine, the contact relationship can contribute to positive results. Two case histories are described briefly.

CARROLL COUNTY, GEORGIA:

Over a period of several years, three wells were drilled on this property (Figure 2); one domestic well and two for chicken farming. No records are available, but the property owner described these wells as:

- Well 1 Domestic well; greater than 200 feet deep; yield approximately 2 gallons per minute (gpm).
- Well 2 Chicken farming well; greater than 200 feet deep; yield less than 1 gpm.
- Well 3 Chicken farming well; yield approximately 6 gpm from gravel-packed zone at the saprolite/hardrock interface (transition zone).

The water in these wells was described as coming from a "shallow" depth.

In the spring of 1994, construction of additional chicken houses required more water. The yield of the gravel-pack well had decreased and an effort to recondition that well had negative results. A fourth well was drilled to a depth of 125 feet, and had a yield of 2 gpm. The driller stopped at 125 feet after unexpectedly encountering granite. The hole had started in an interlayered amphibolite/biotite-quartz-feldspar gneiss/quartz-feldspar-muscovite schist sequence which had potential for moderate well yield.

At this point, the well driller sought assistance in interpreting the geologic setting. Reconnaissance geologic mapping of Carroll County in 1969 showed a small granite body approximately 1.5 miles long and less than a 0.5 mile wide just north of the wells, with its southern end (of outcrop) a few hundred yards north of the wells.

Detailed geologic mapping showed that this granite extends further southward, onto the property. Results of the drilling show that this granite body continues still further southward in the subsurface, beneath the amphibolite/gneiss/schist sequence; and that the contact between these two lithologies dips at a very low angle, much less than the dominant 40 to 60 degree dips of foliation in the overlying amphibolite/gneiss/schist (Figure 2).

This granite is of uniform composition and massive; joints are scarce and widely spaced. It has very little pre-

dictable potential for large-yield wells. The broad alluviated valley to the north of the chicken houses offers good opportunity for ground water recharge, but was avoided in drilling-site selection because it is underlain by this granite.

The alternative was to select sites near the other wells, with an effort to position the sites for maximum joint and foliation intersections, and maximum recharge, while still drilling the hole in the amphibolite/gneiss/schist sequence. Because the granite was being intercepted at shallow depths, deep drilling was considered inappropriate.

Two wells were drilled:

- (1) Well 5 Total depth, 150 feet; yield 5 gpm.
- (2) Well 6 Total depth, 125 feet; yield 30 gpm, primarily from a depth of 70 feet.

Well 6 supplies more than enough water to operate all of the chicken houses, producing from the amphibolite/gneiss/schist sequence which overlies the massive granite.

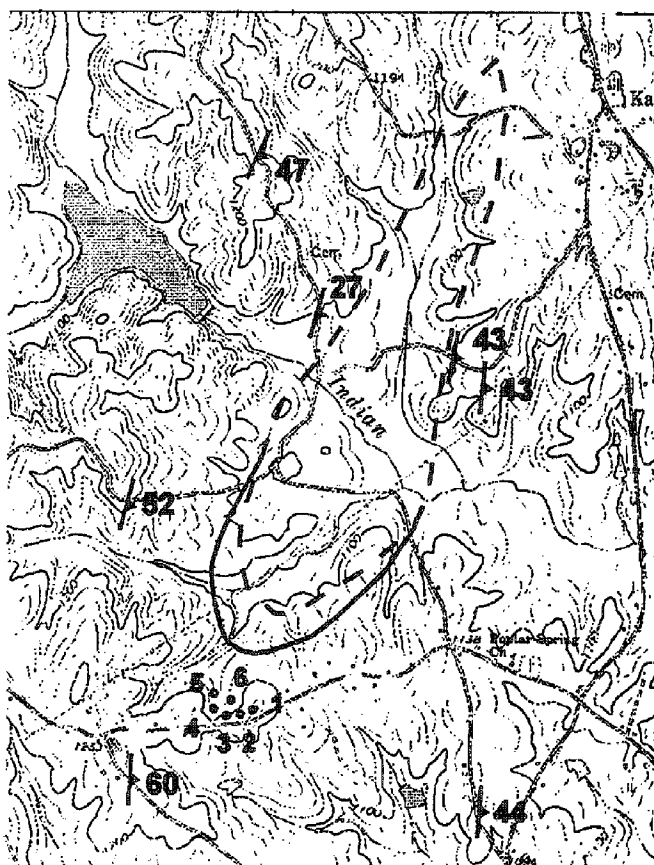


Figure 2. Well Locations, Structure and Granite Body Limits from Reconnaissance Mapping (dashed) and as Extended to the South by Detailed Mapping (solid). (From the Bowden West, GA-ALA, 7.5-min. Quadrangle)

SPALDING COUNTY, GEORGIA

In the summer of 1992, a decision was made to drill water wells at the University of Georgia Experiment Station for the purpose of agricultural irrigation. An existing "old" farm well reportedly had a yield estimated at about 20-25 gpm. This is a "deep bedrock" well. No pumping test was performed; there was little interest in using this as an irrigation water source.

Assistance in ground-water exploration was solicited, and a drilling site was selected near the intersection of two small valleys, one trending northeast, the other trending northwest.

This site is near a major lithologic contact, between a dominantly schist unit and a dominantly gneiss unit. The site was selected with the intention of drilling into the schist. If the lithologic contact followed the "accepted norm" for southeastern Piedmont/Blue Ridge regional orientation, that is, striking northeast and dipping southeast at moderate to steep angles, this well, started at or near the contact, would have been drilled entirely in the schist unit.

However, drill cuttings show that the well started in the gneiss unit, and stayed in the gneiss to its total depth of 605 feet. A water-bearing "fracture" at 76 feet yielded about 5 gpm, and another at 91 feet yielded about the same, for a total of approximately 10 gpm. Cuttings show these water-bearing zones to be rich in biotite. This test well was not completed as a production well.

The disappointing results from this deep hole suggested that additional guidelines must be developed, and a further evaluation of the ground water potential of this part of the Farm Property was undertaken (Figure 3).

Detailed geologic mapping revealed the following relationships:

1. Most of the property is underlain by two dominant rock types:

- a) **Schist**, comprised of graphite, muscovite, chlorite, sillimanite, quartz, feldspar, and biotite; garnets are small and scarce; pyrite occurs throughout; the schist is fine- to coarse-grained. Mineral composition is extremely variable over short distances, particularly the abundance of sillimanite, graphite, and feldspar. Gondite, a rock composed primarily of garnet and quartz, occurs as thin layers and lenses throughout the schist. Quartz veins are small and scattered. Feldspathic zones and pegmatites are abundant and large enough to have a positive influence on ground water potential. This lithologic unit contains, in the western part of the property, layers and lenses of feldspar-hornblende gneiss, fine- to medium-grained. The

gneiss is well-foliated and has a distinctive "slabby" weathering characteristic.

- b) **Gneiss/Granite** comprised of biotite-quartz and feldspar.
2. Depth of weathering in both major lithologies is shallow, ranging from just a few feet to several tens of feet. Ground water potential depends on depth of weathering, development of foliation and fractures, and fracture concentrations.
 3. Differential weathering along foliation (Compositional layering) is not well developed, and has produced no well-defined zones of secondary permeability. The strike of foliation varies over short distances; where measurable, the general trend is north-northwest inclined to the northeast at moderate to steep angles (57 to 78 degrees). Joints are not well developed in these rocks.
 4. The property occupies the gentle hill slopes and inter-tributary divides of the headwaters of Shoal Creek. Local topographic relief is about 80 to 100 feet; topo-

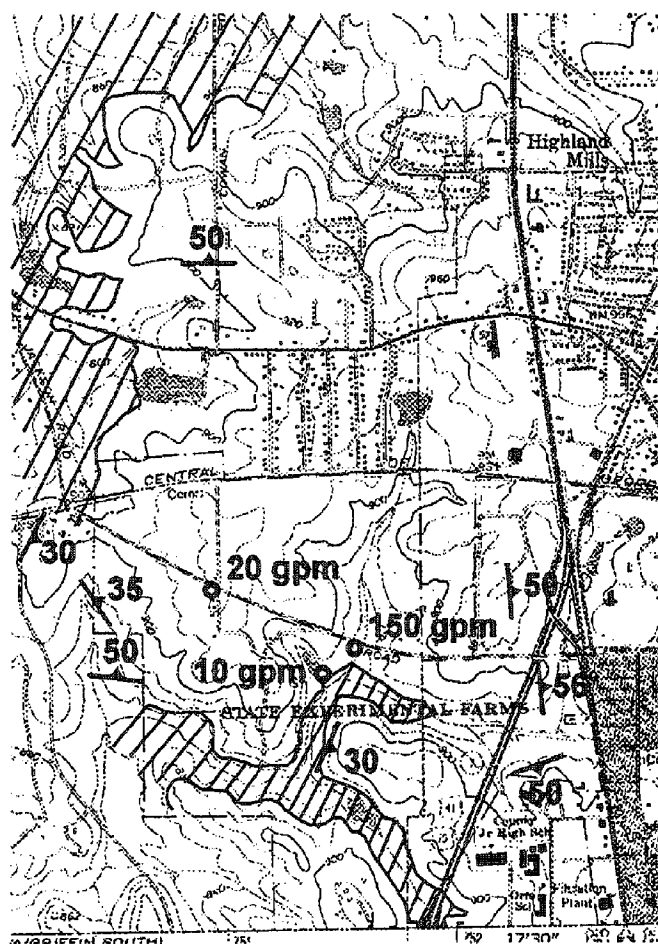


Figure 3. Well Locations and Structure with Outcrop of Granitic Gneiss (hatch) (from the Griffin North 7.5-min. Quadrangle).

graphic setting is good: with moderate relief and gentle slopes, precipitation has an opportunity to infiltrate and charge/recharge the ground water.

5. Weathering is very shallow along the major drainage courses, which are developed on the gneiss/granite. Stream-bed exposures show this rock unit to be massive, with only scarce and poorly developed discontinuities; this rock unit has very low potential for large-yield wells.
6. The best development of differential weathering along joints, foliation, and compositional layering, with some potential for large-yield wells and sustained production, is along the north-south trending Shoal Creek tributary which crosses Ellis Road.
7. The relationship between surface and subsurface distribution of the schist and the gneiss/granite is critical for well-site selection. The well drilled July 2, 1992, gave some information on this relationship; detailed geologic mapping provided additional information used in site selection.

Areal distribution of the two major lithologies shows that the schist structurally overlies the gneiss, and that the contact is sub-horizontal and undulatory. The gneiss is exposed mostly along the stream courses, where erosion has removed the overlying schist (Figure 3).

Having established this relationship and knowing that the massive gneiss offers little potential for large-yield wells posed a dilemma: the broad valleys occupied by second-order streams, which ordinarily provide attractive exploration sites, did not have good ground water potential in this geologic setting.

Detailed geologic mapping showed that the schist "cover" unit occupies the valley floor approximately 600 feet north of the first well. Interpretation of the low-angle lithologic contact indicated that the schist "cover" unit was thick enough in this area to store and transmit significant amounts of ground water. Based on this interpretation, a drilling site was selected.

Results of drilling:

1. Water-bearing zones were encountered at 52 feet, 64 feet, and 82 feet.
2. During a short-term (9-hour) pumping test, the drawdown stabilized at 150 feet below ground surface (142 feet of drawdown) at a pumping rate of 150 gpm; there was 97 percent recovery after one hour.

This well should sustain production of more than 100 gpm.

SUMMARY STATEMENT

In both cases described here, contact relationships of major lithologic units are quite different from the general concept of Piedmont/Blue Ridge lithologic contacts. Determination of the nature of, and details of, the lithologic unit contacts in these areas was essential for positive results in the ground water exploration programs. Detailed geologic mapping was the only feasible approach to determining the subsurface distribution of the target lithology, which offered the best potential for ground water yield.

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